A SERVICE CURVE APPROACH TO DEMAND RESPONSE

Jean-Yves Le Boudec
Dan-Cristian Tomozei

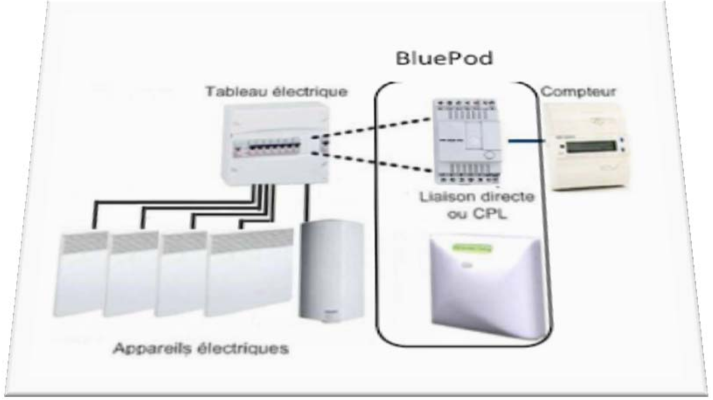
ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Agenda

- Demand Response
- Service Curve Approach
- User Side Optimization
- Operator Side Optimization

Demand Response

- Some Demand can be delayed !
- DSO provides best effort service with statistical guarantees [Keshav and Rosenberg 2010]



Voltalis Bluepod switches off thermal load for 30 mn

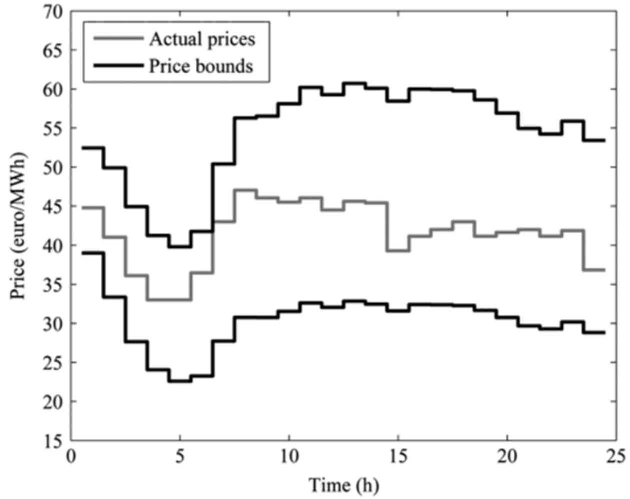
Programmable dishwasher

PeakSaver cycles AC for 15mn

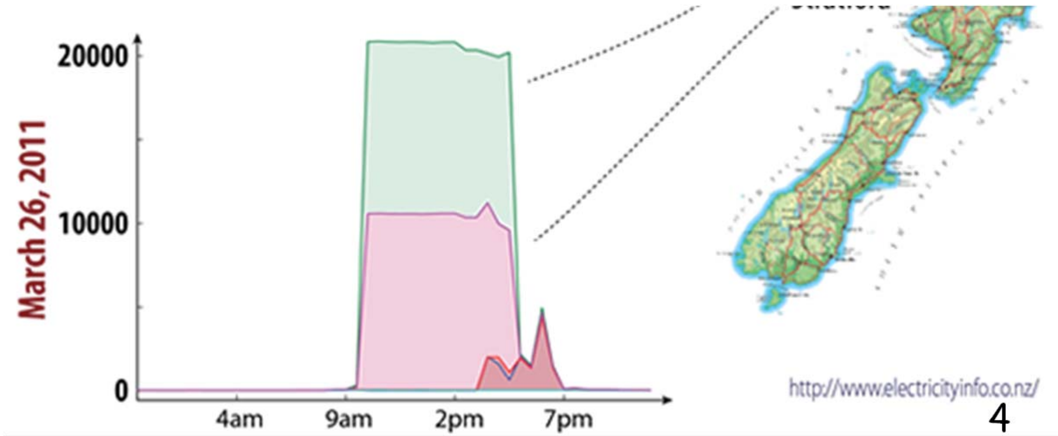
Price vs Quantity

- Peaksaver, Bluepod act by quantity control
  - DSO/Aggregator switches off appliance
- Price control often proposed as alternative
  - Users save when price is high

[Conejo et al, 2010]

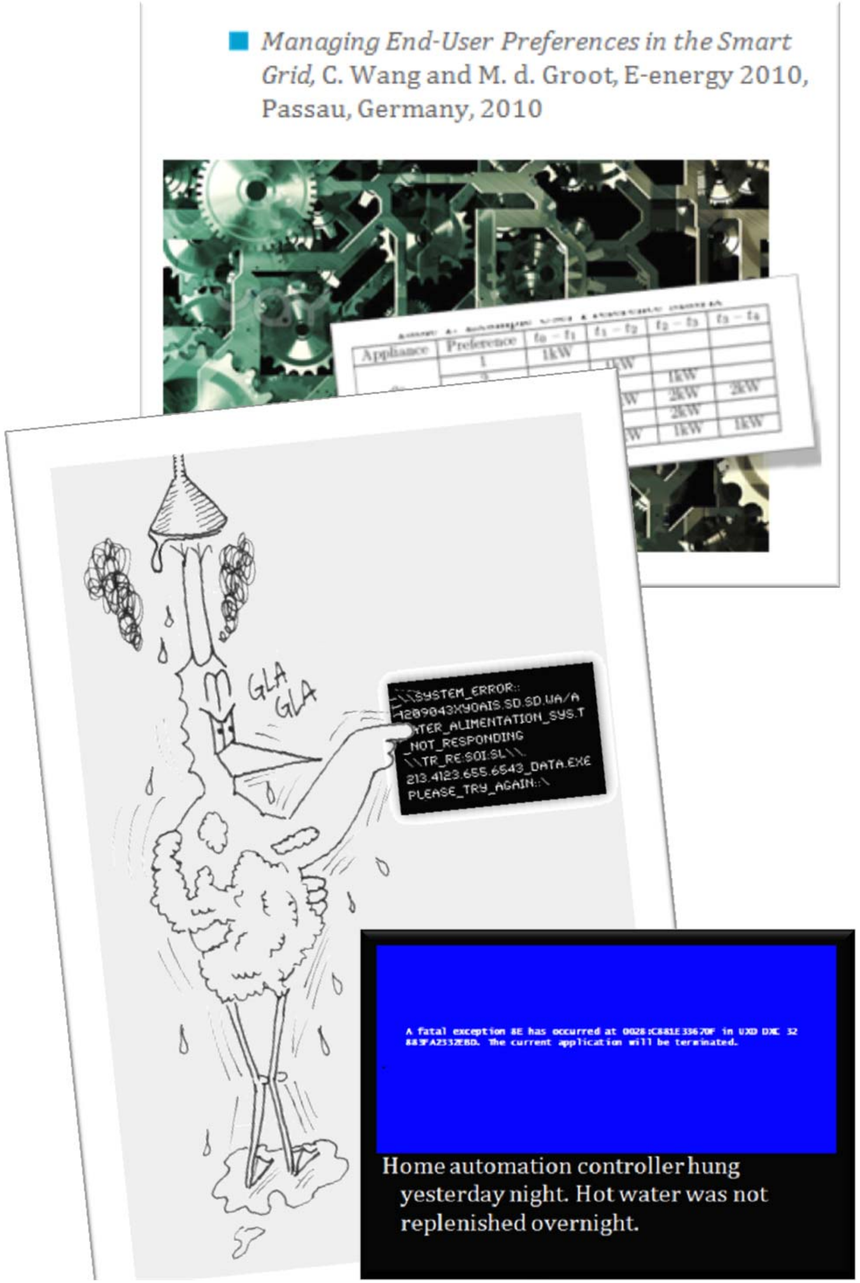


- [Meyn 2010] : high volatility is an inherent feature of electricity markets



Centralized vs Distributed Control

- Direct control by DSO/Aggregator for air conditioning, dryers
- Not scalable, does not adapt to diversity and flexibility
- Appliance control should be done close to end-users



Price Based Approach

\+ Distributed, flexible, user can interact

\- Volatility, Reconciliation, Predictability

Quantity Based Approach

\+ Predictable costs

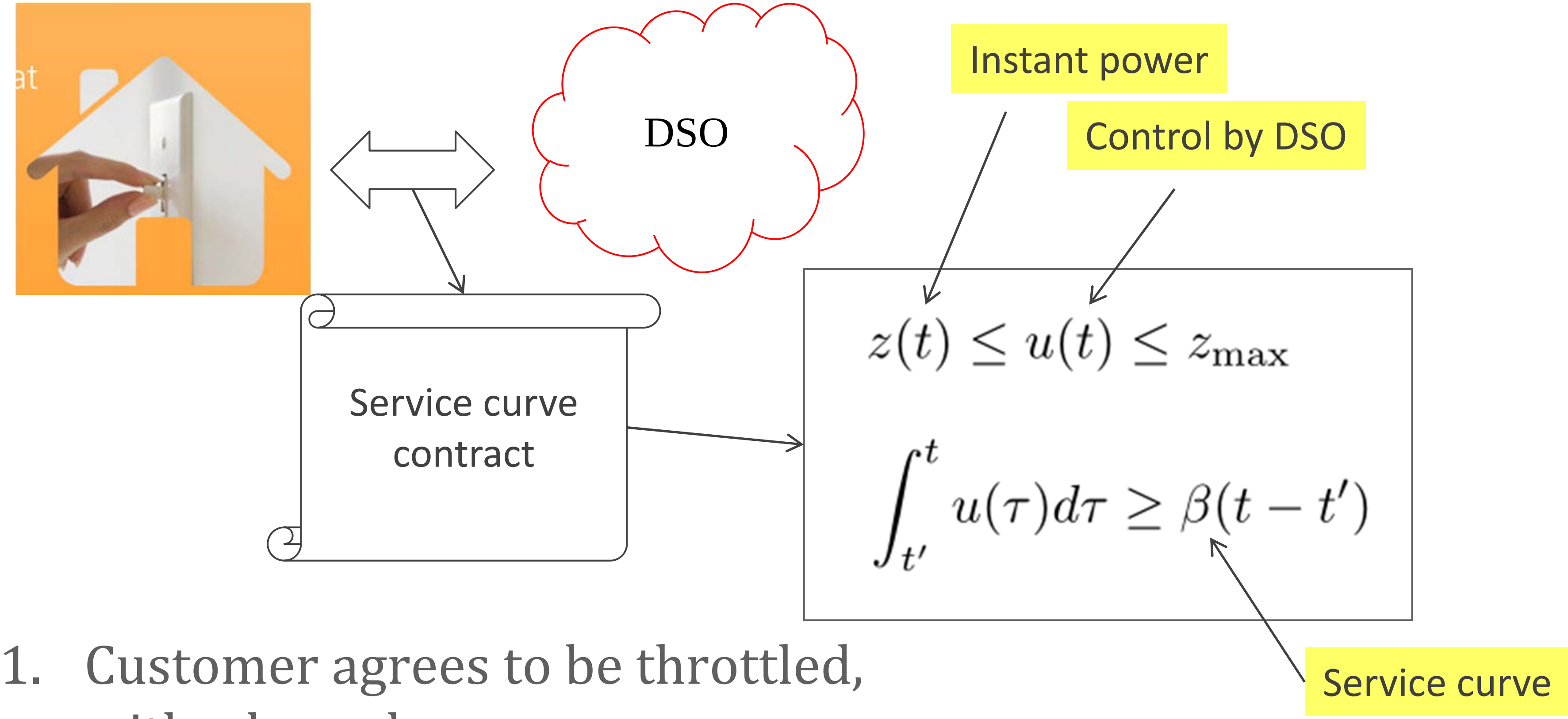
\- Centralized, inflexible, no user input

Service Curve Approach

\+ Distributed, flexible, user can interact

\+ Predictable costs

Definition of Service Curve Approach

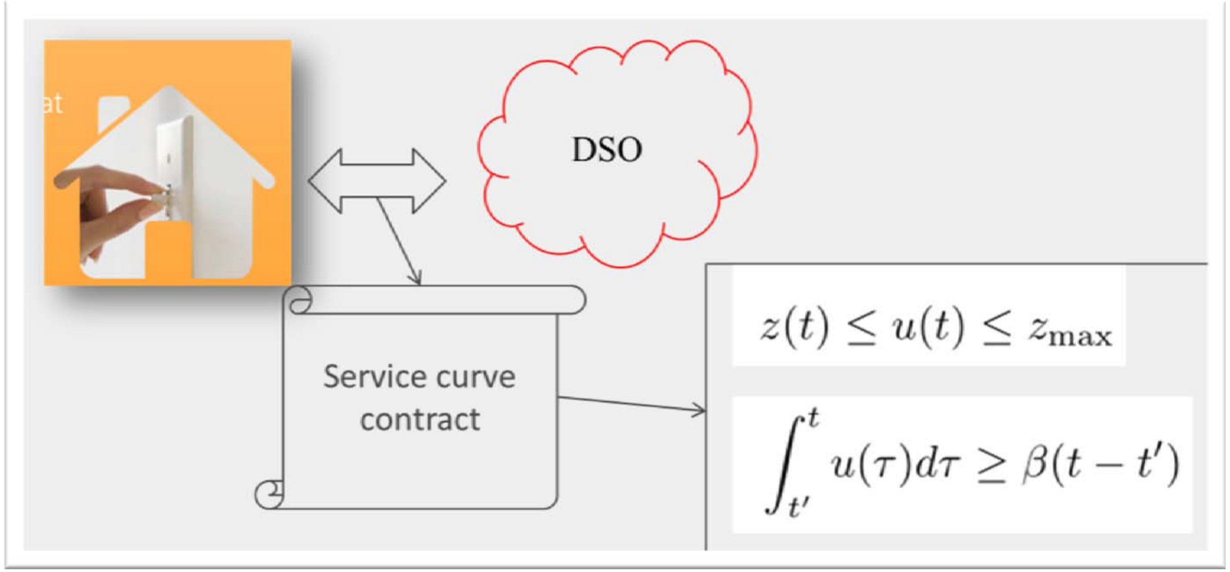


$$z(t) \le u(t) \le z_{\max}$$

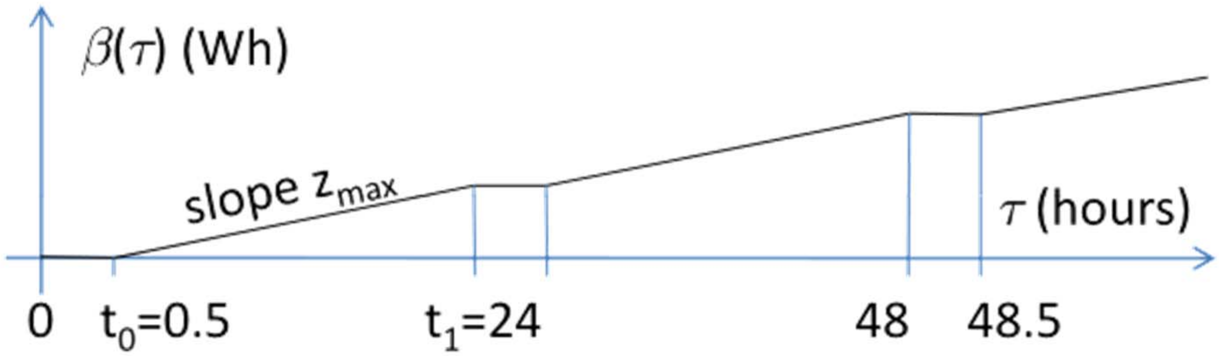
$$\int_{t'}^{t} u(\tau)d\tau \ge \beta(t-t')$$

1. Customer agrees to be throttled, with a bound
2. Fixed price per kWh
3. Total load is controlled

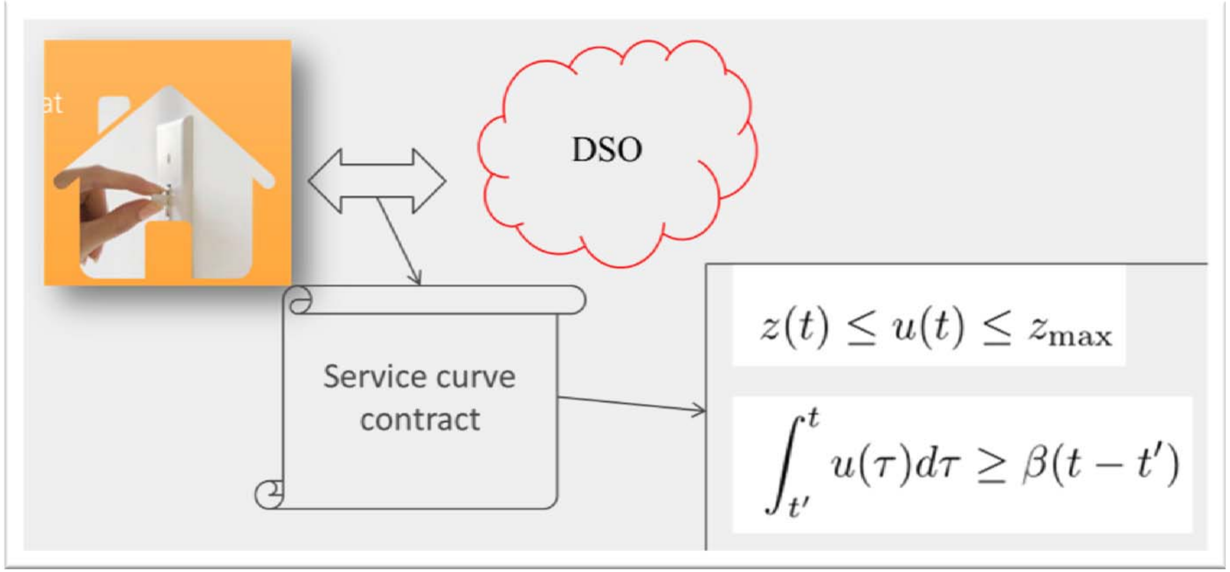
Example 1: Load Switching



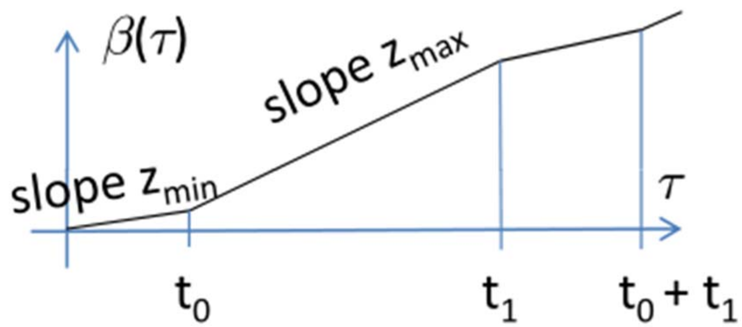
- At most 30 mn of interruption total per day
- Or reduction to $\frac{z_{max}}{2}$ for 60mn total per day



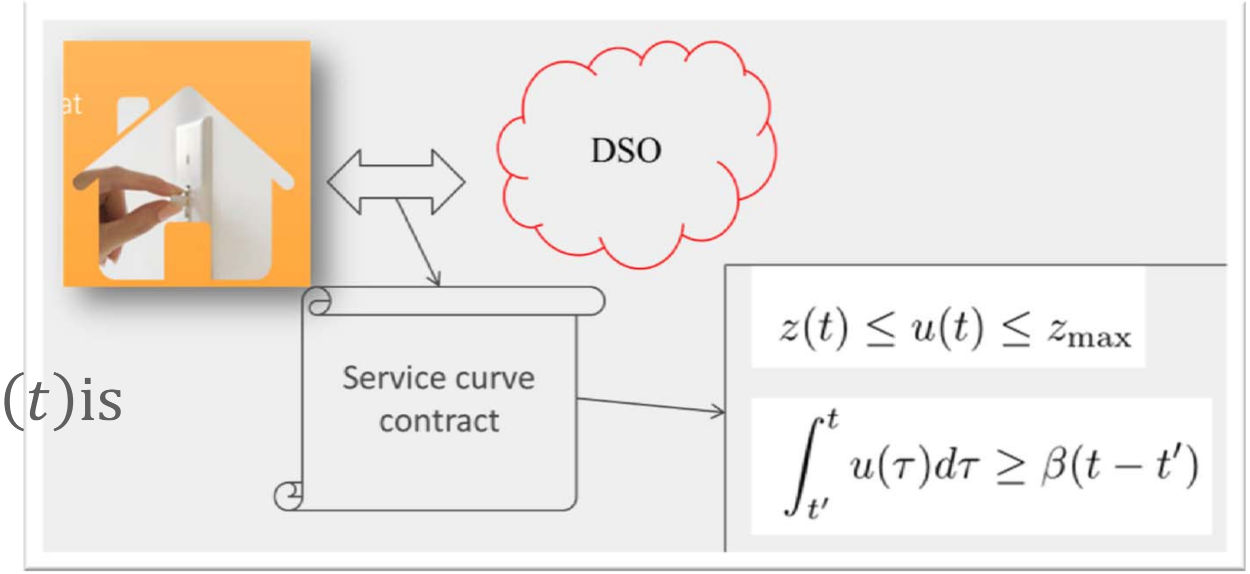
Example 2: Two Level Control



- Similar, but a minimum power z_{min} is guaranteed
- Better suited (than ex 1) when applied to an entire home /enterprise



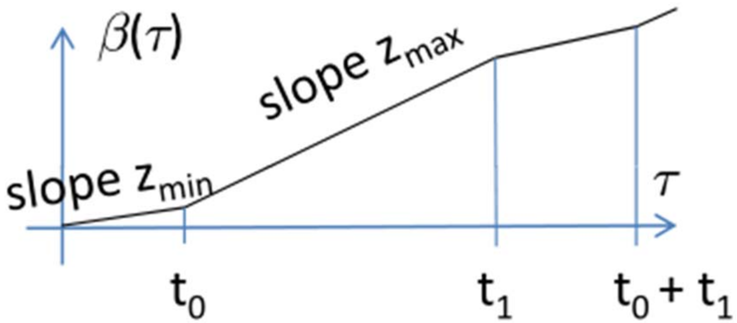
The Maths of Two-Level Control



- The constraint on $u(t)$ is equivalent to

$$u(t) \geq z_{min}$$
$$\int_t^{t + t\_1} u(s)ds \geq A$$

- i.e. the allowed energy per window of time t_1 is lower bounded



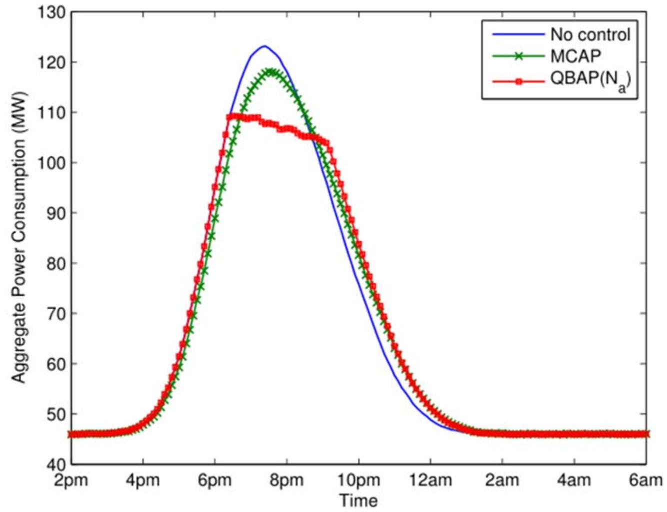
User Side Optimization

- User can observe past signals and predict worst case future
- Smart home controller can manage load accordingly

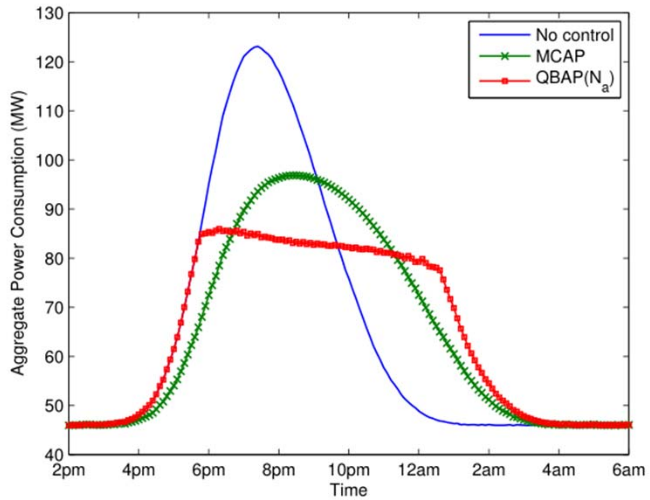
[LeBoudec Tomozei 2011]

Provider Side Optimization

- Provider may send smooth signals
  - E.g. $u(t) = 2\, z_{min}$ to many customers, for long periods of time
- Or bursty signals
  - E.g. $u(t) = z_{min}$ to selected customers, for shorter periods of time
- Smooth signals are optimal for stationary but random loads, bursty signal are better for shaving peaks

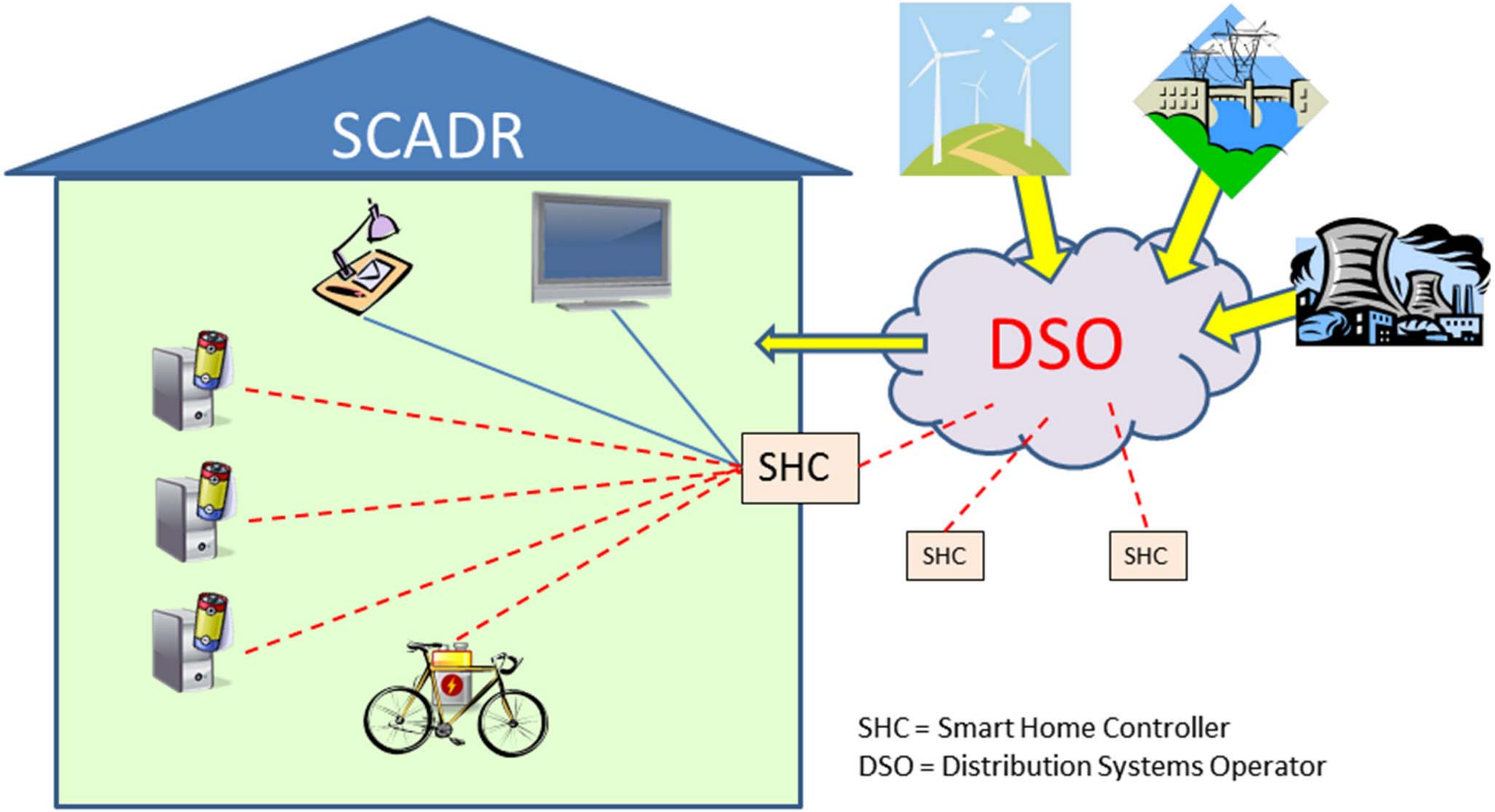


(a) $t_0 = 30\text{mn}$, quota $N_a = 6100$



(b) $t_0 = 3\text{h}$, quota $N_a = 3500$.

EPFL Testbed



SHC = Smart Home Controller
DSO = Distribution Systems Operator

Conclusions

- We propose a service curve approach to demand response
- Distributed
  Applies to total customer load
  Provides large flxibility to provider
  Protects user from price uncertainty

[Le Boudec Tomezei 2011] Le Boudec J.Y. and Tomozei, D.C “Demand Response Using Service Curves”, EPFL-REPORT-168868, https://infoscience.epfl.ch/record/168868, 2011